ν_e CC selection, ν NC rejection

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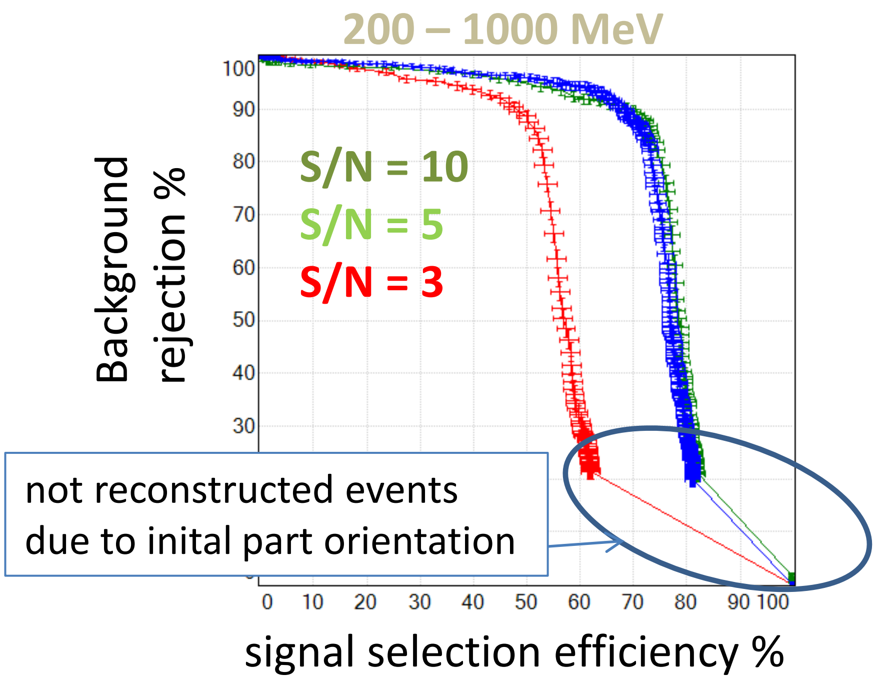
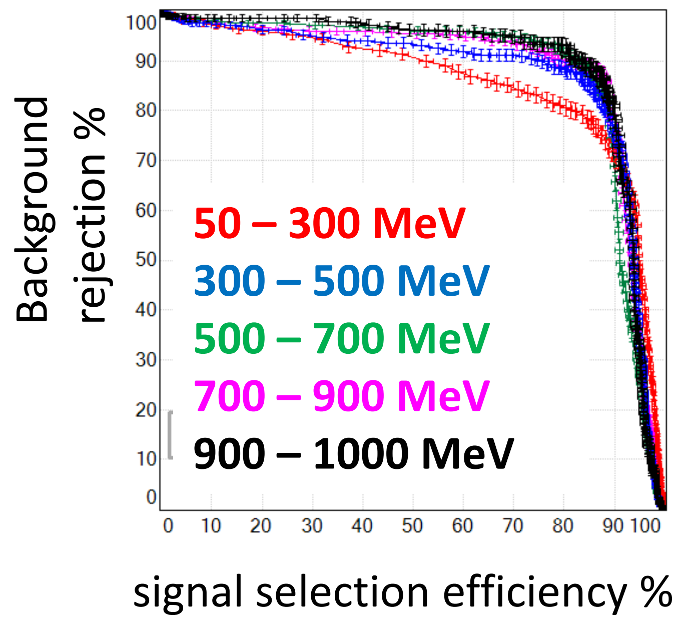
Outline

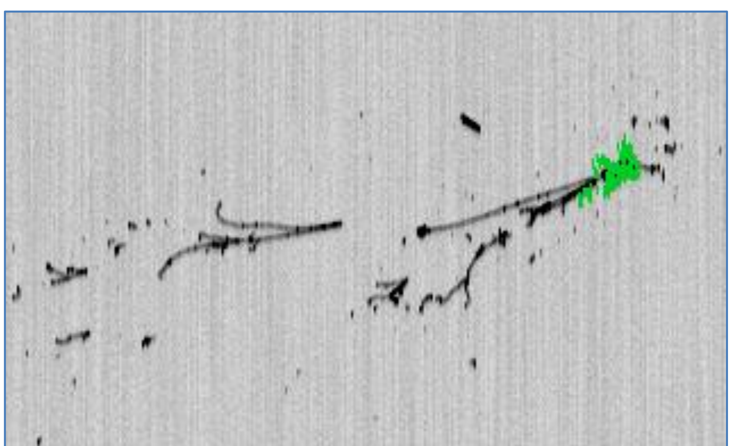
- **Aim**: estimation of ν_eCC selection efficiency as a function of background rejection in neutrino events.
- Simulation done by Paola in FLUKA: ν_eCC and ν NC with neutrino momenta bins: 1 GeV/c, 2 GeV/c, 3 GeV/c, 4 GeV/c (with APA, 4.67 mm wire pitch, +/- 35.7 deg).
- In ν_eCC we are looking for electron showers from primary vertex, background comes from γ's from π^0 generated in ν NC events.
- Use combination of reconstruction available in LArSoft and RECO (RECO is used in ICARUS) and also some support from MC information.
- Combination of MC information with reconstruction helps to understand main difficulties and needs for the future development of reconstruction and analysis approaches (independently from frameworks).
- Why use RECO framework :
  - a. very well known to me,
  - b. fast compilation so it is more friendly to test many variants,
  - c. visualization easier,
  - d. but no diffusion implemented yet…
- Use full reconstruction from MCC in LArSoft to compare results.

Reminder of some results for single showers:

used only dE/dx of the initial part of a cascade (first ~2.5cm)

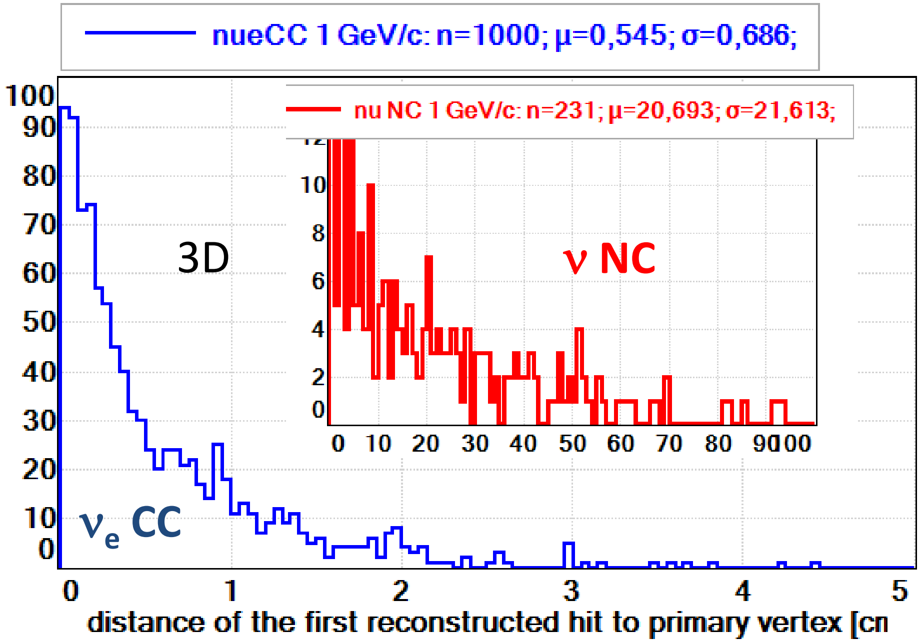


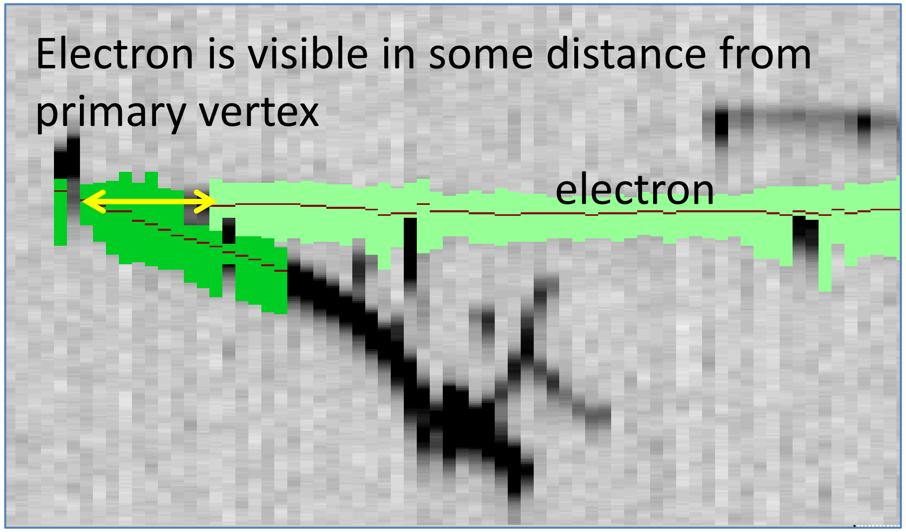


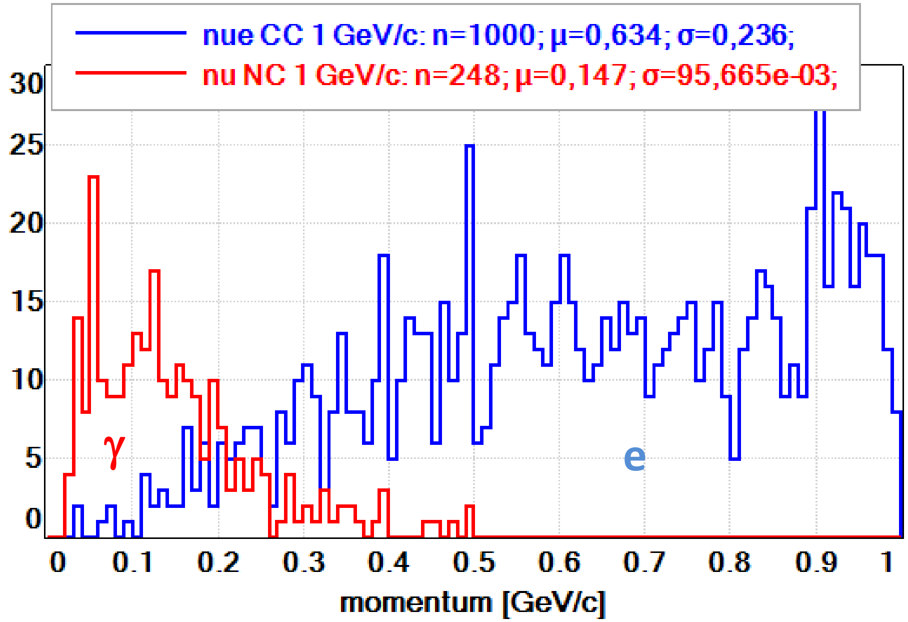


- Example of an event for which initial track was not reconstructed: shower covers first part of a cascade.
- In this approach not reconstructed showers affect signal selection efficiency.

ν_e CC, ν NC 1 GeV/c

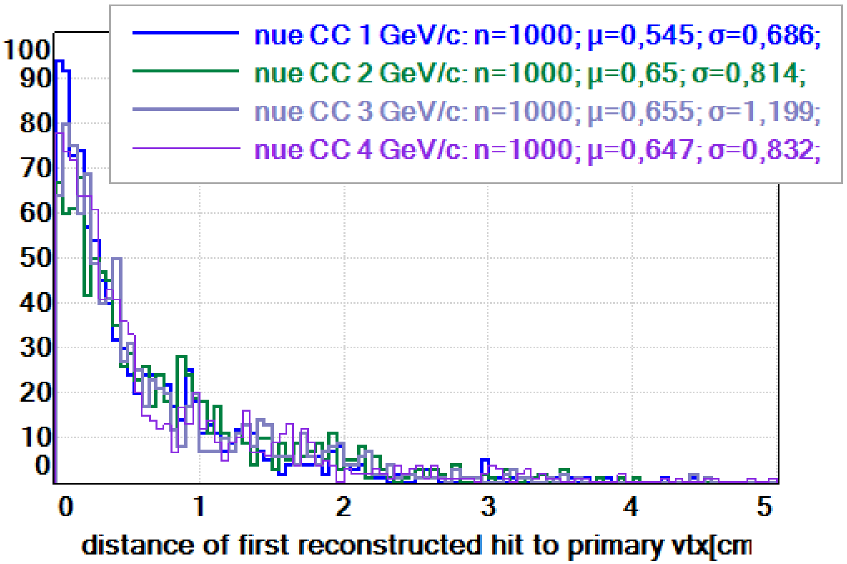


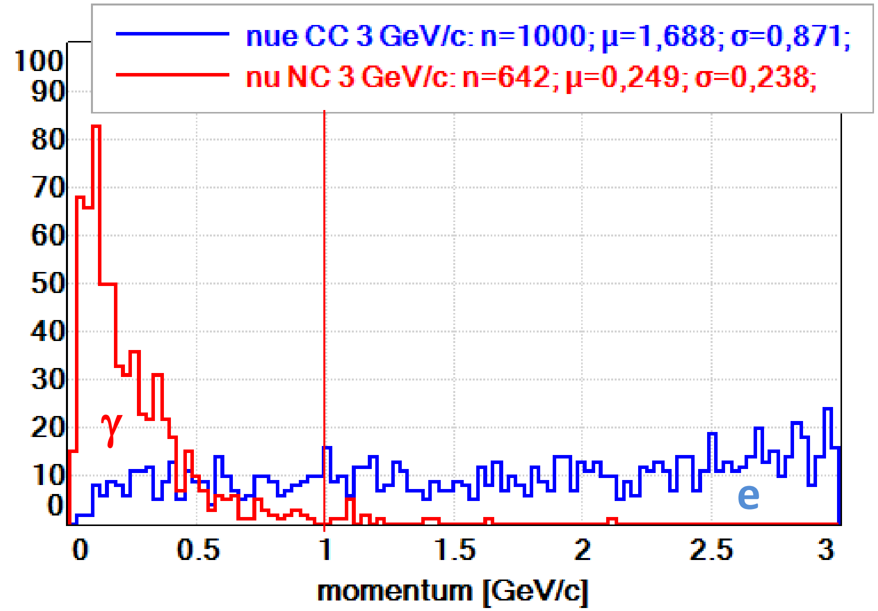


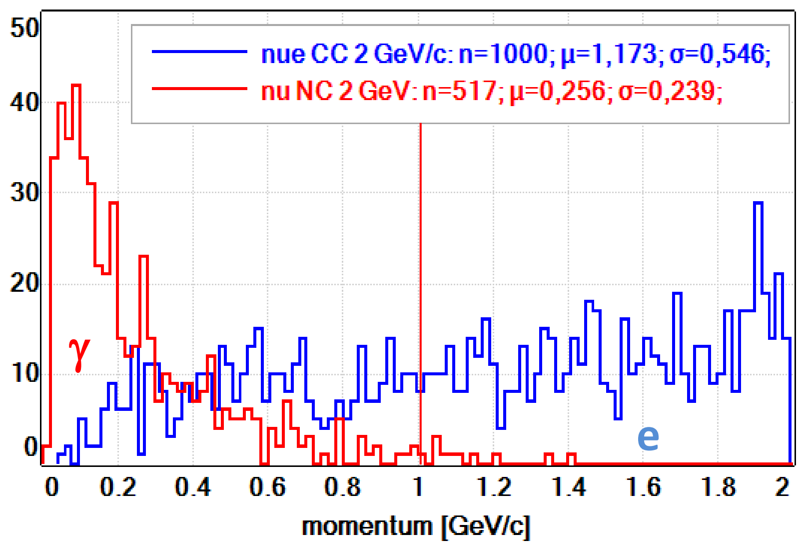


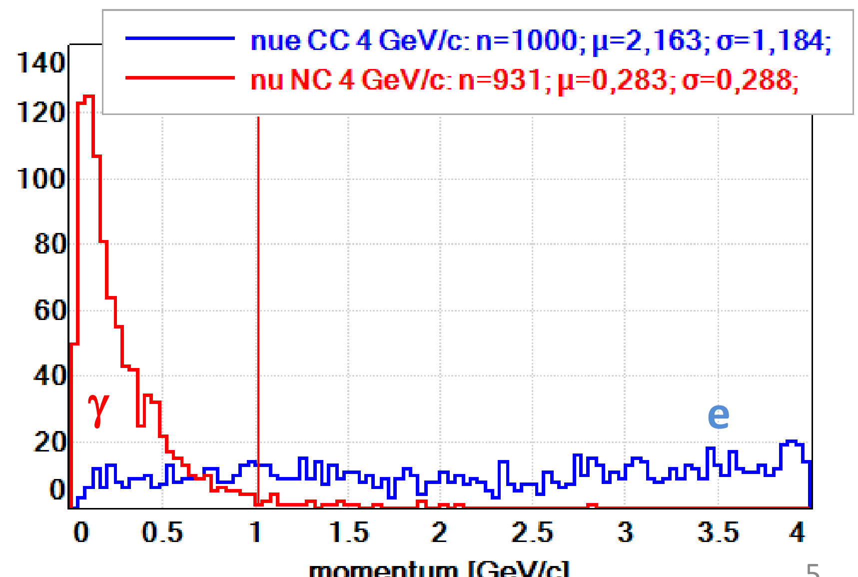
- One of the **discriminant** can be a **distance between primary vertex and first reconstructed hit of the electron track**.
- Cut on momentum of cascade (if we can reconstruct it) will have impact on electron selection efficiency.

ν_e CC, ν_μ NC 2 GeV/c, 3 GeV/c, 4GeV/c

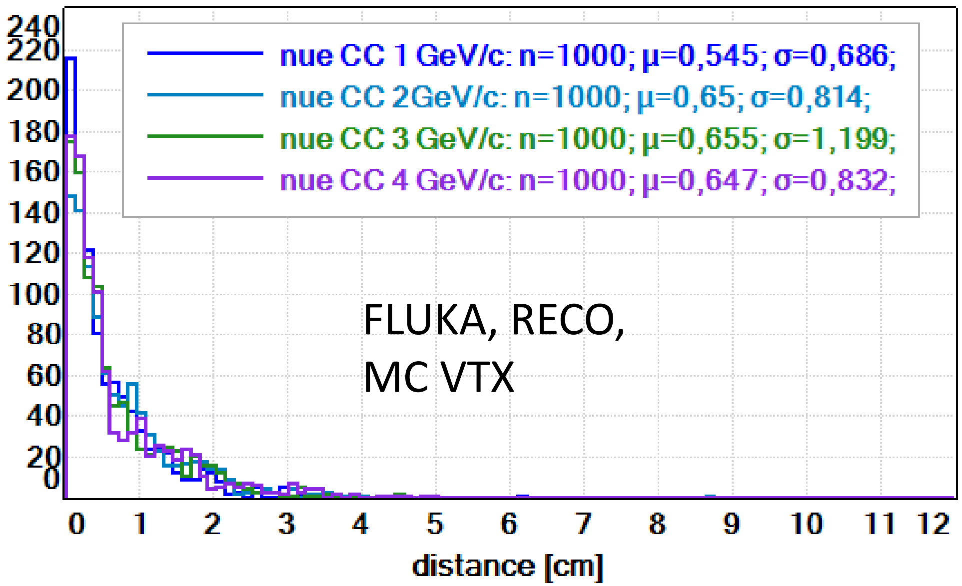


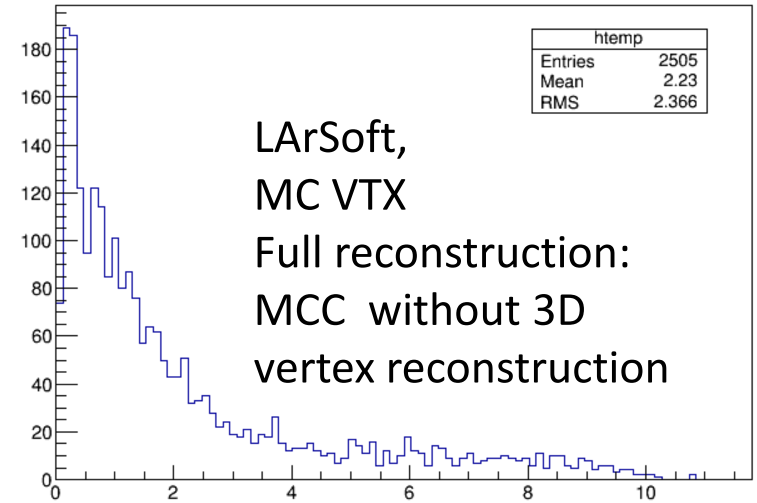




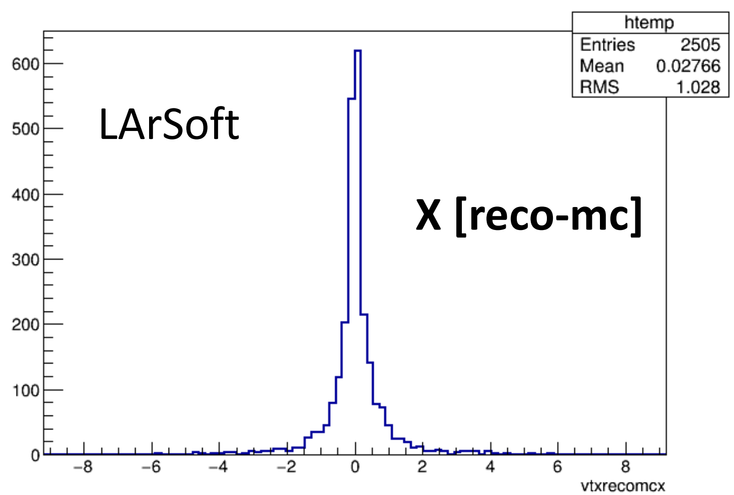


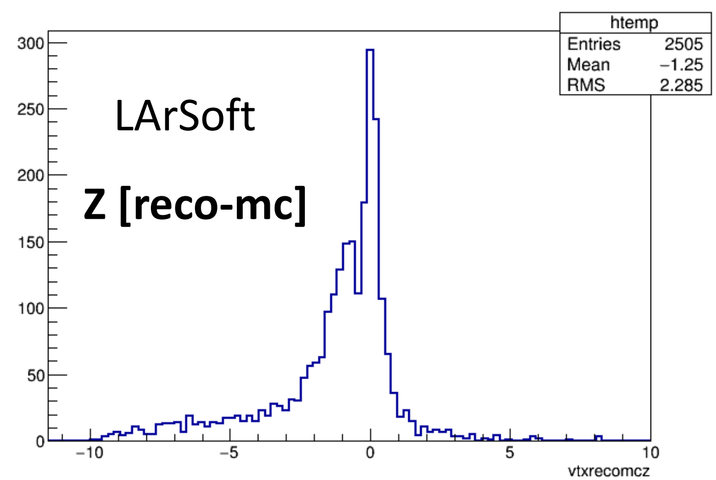
Distance of reconstructed start of a shower in RECO & LARSOFT



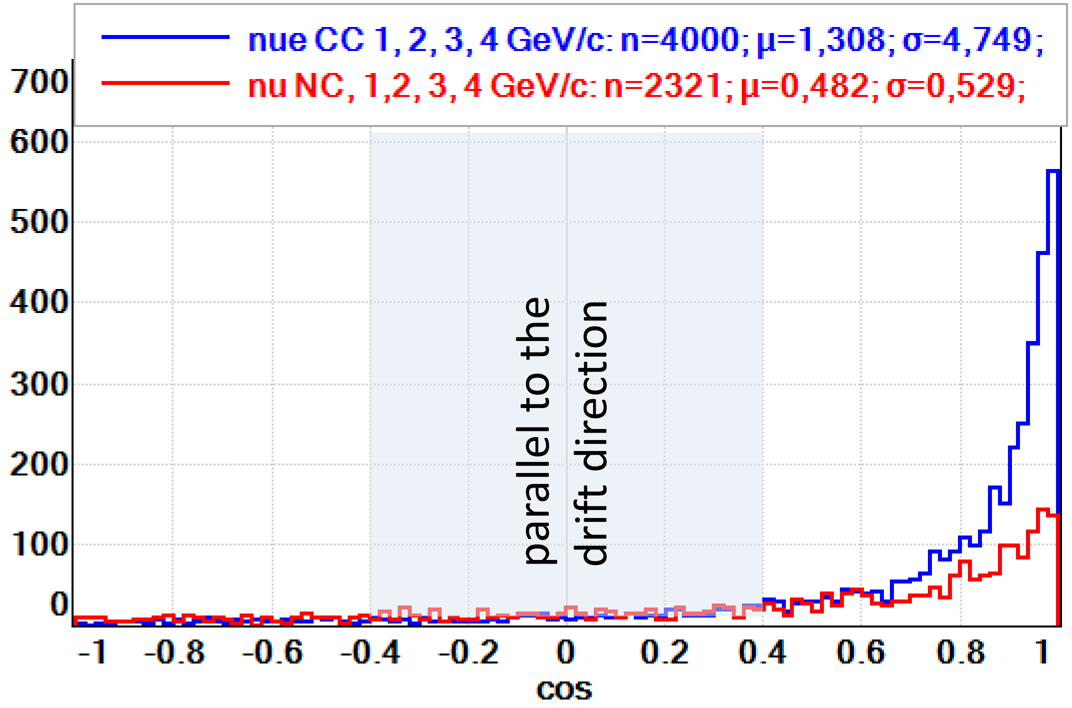


distance of first reconstructed hit to primary vtx [cm]





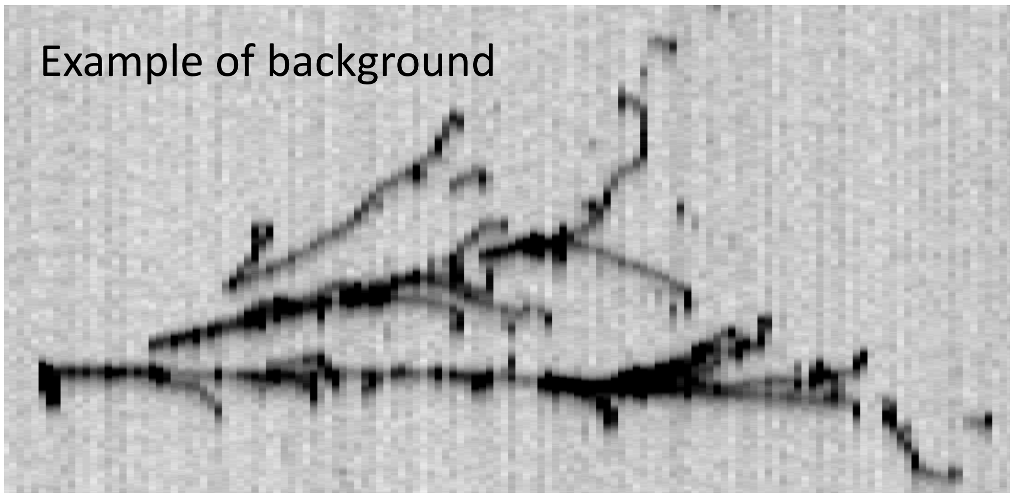
Angular distribution of electrons and photons in generated neutrino events

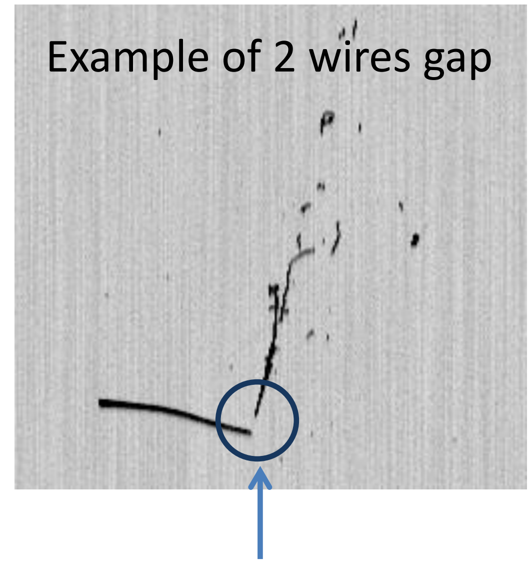


electrons can go even backwards – any angular cut will affect signal selection efficiency: for example: cut on cos in a range: (-0.4, 0.4) will cause 10% electron inefficiency.

Gap is a better discriminant than distance of first reconstructed hit to primary vertex

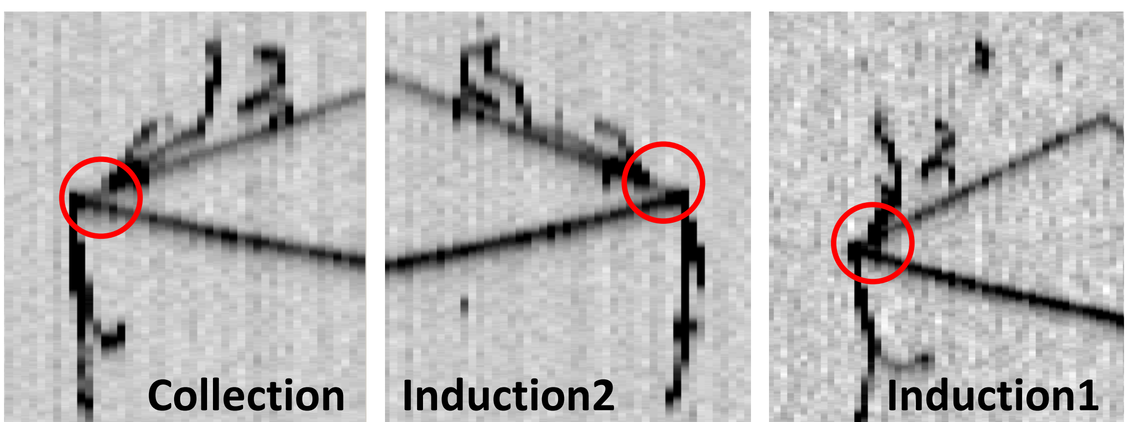
- Number of wires without signal between primary vertex and first point of a cascade (not a conversion distance).
- Signal: gap < 3





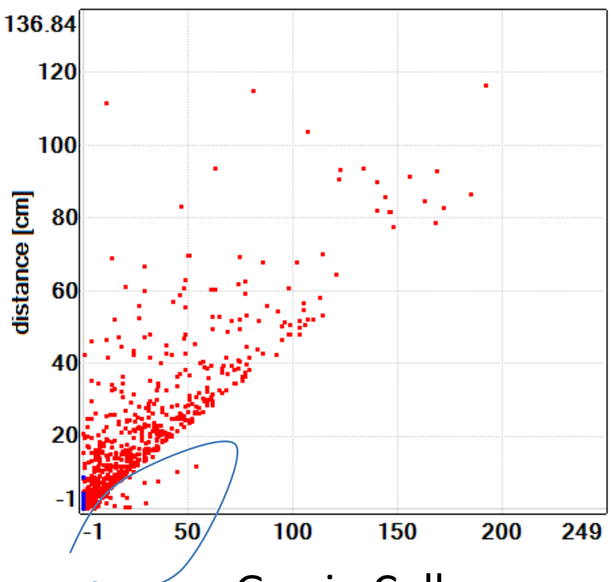
Even if there are 2 wires gap, distance is enough large to recognize background event → we should define a gap in cm.

2 wires gap

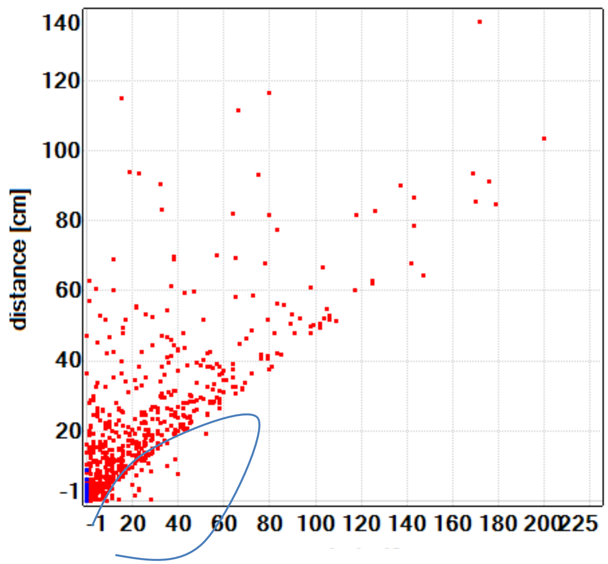


Correlation between two possible discriminants

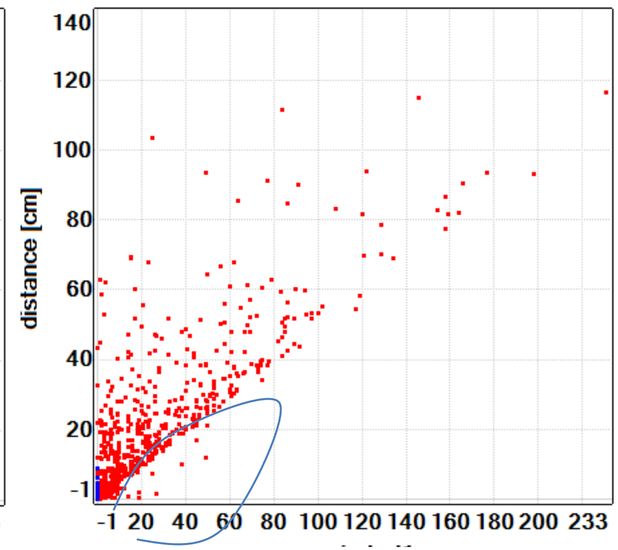
- Distance: first hit of the 3d reconstructed track to primary vtx.
- Gap: maximum number of wires without a signal between primary vtx and the first reconstructed hit in a cascade cluster, computed from 2D clusters in each projection independently.



Gap in Coll

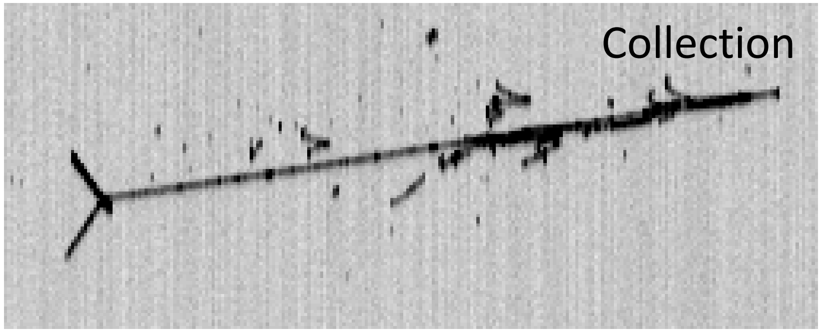


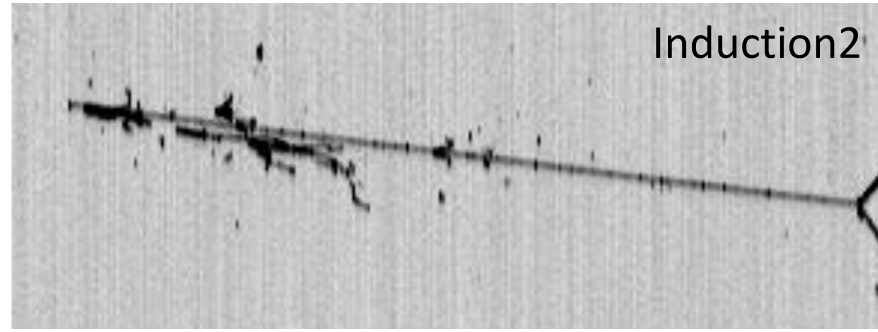
Gap in Ind2

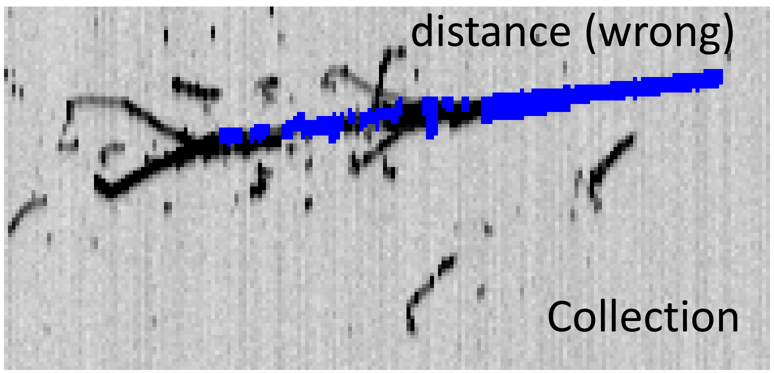


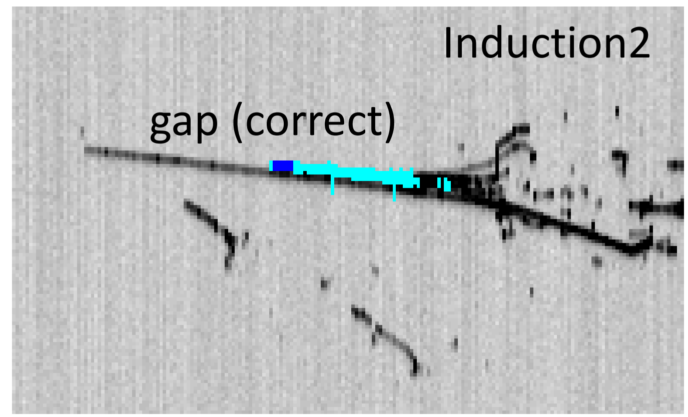
Gap in Ind1

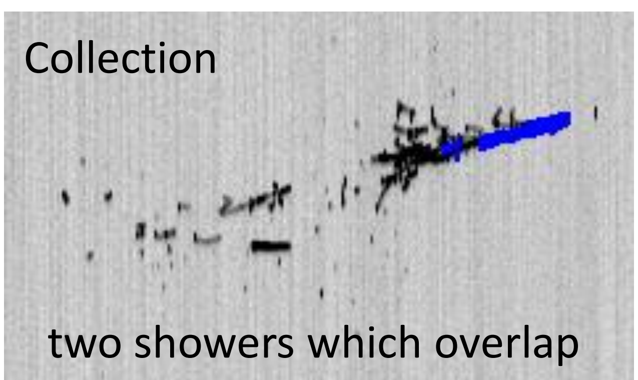
For some events we find much smaller distance than a gap, why? – examples on the next slide.

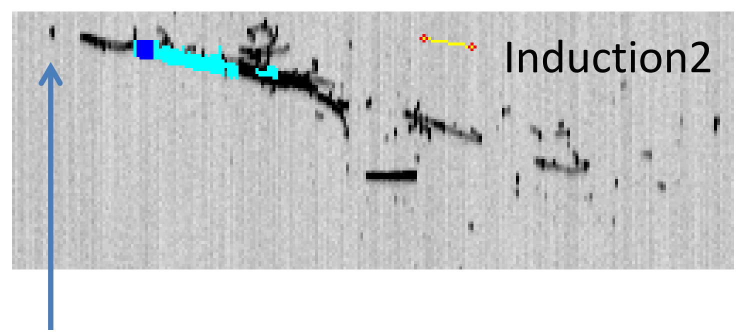








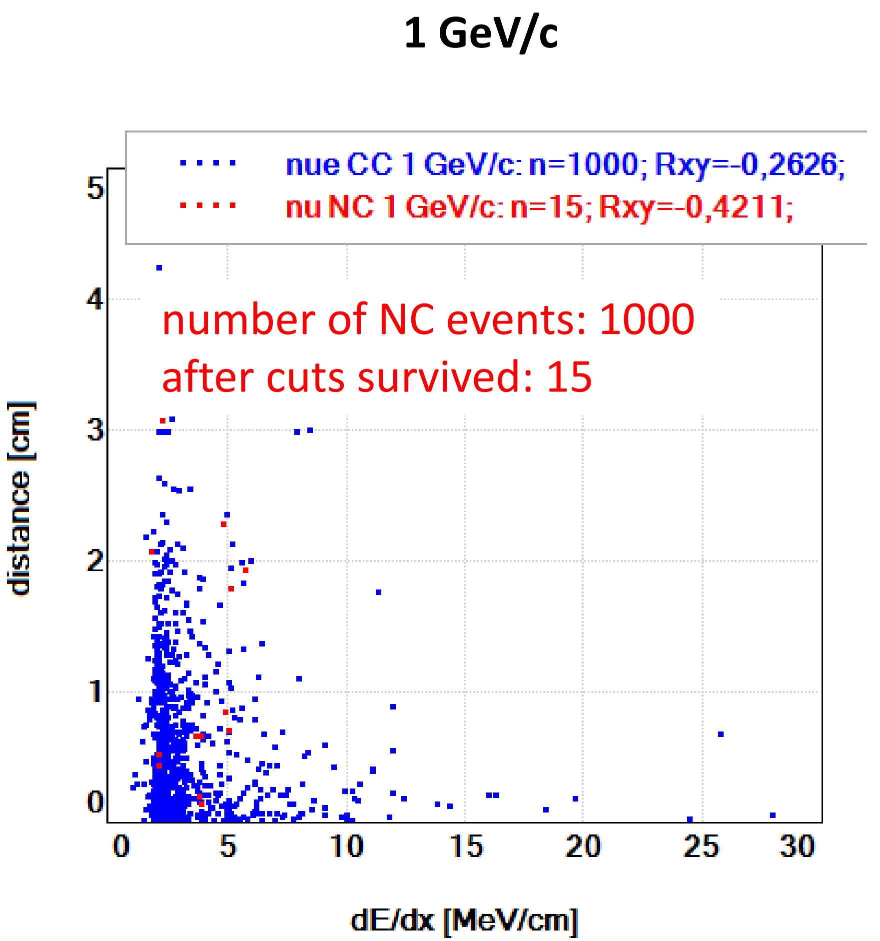


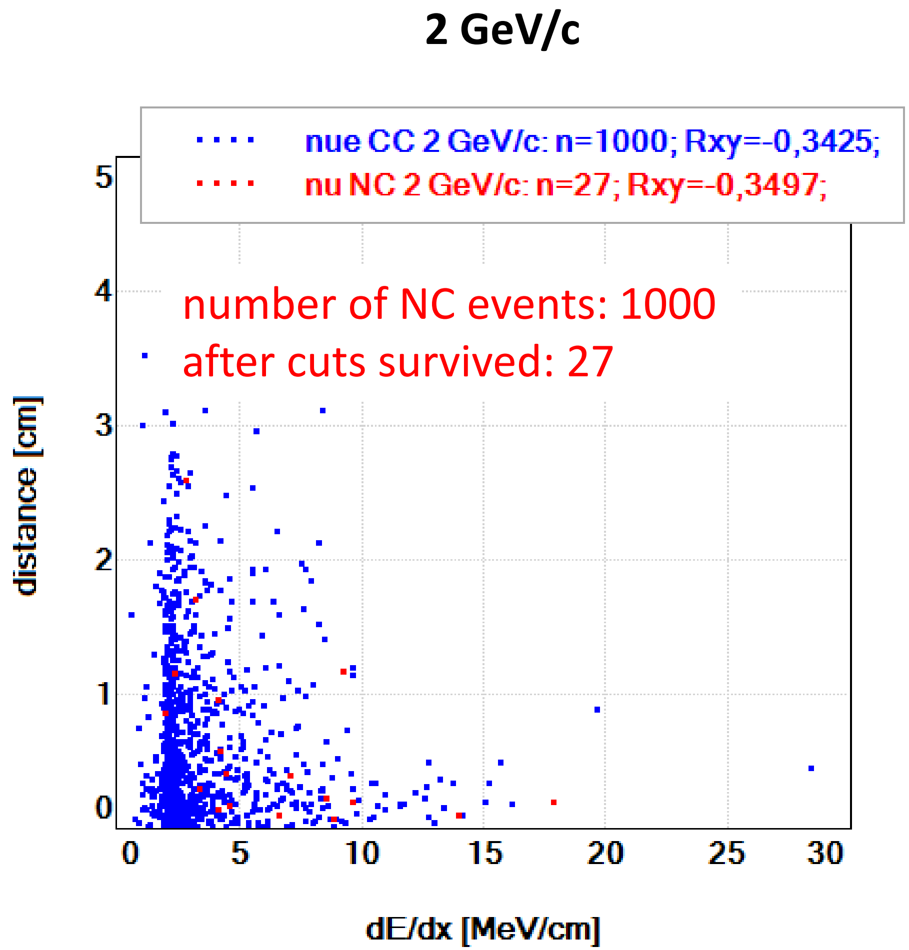


primary vertex

Background rejection

3 views are used

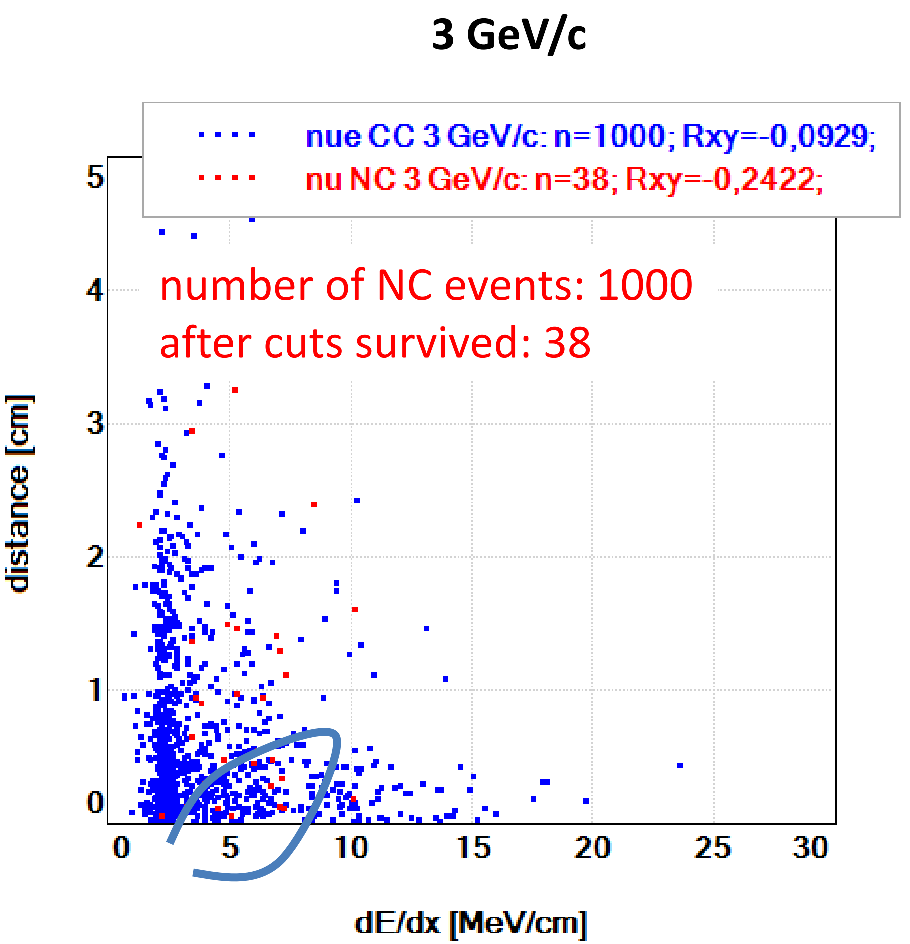


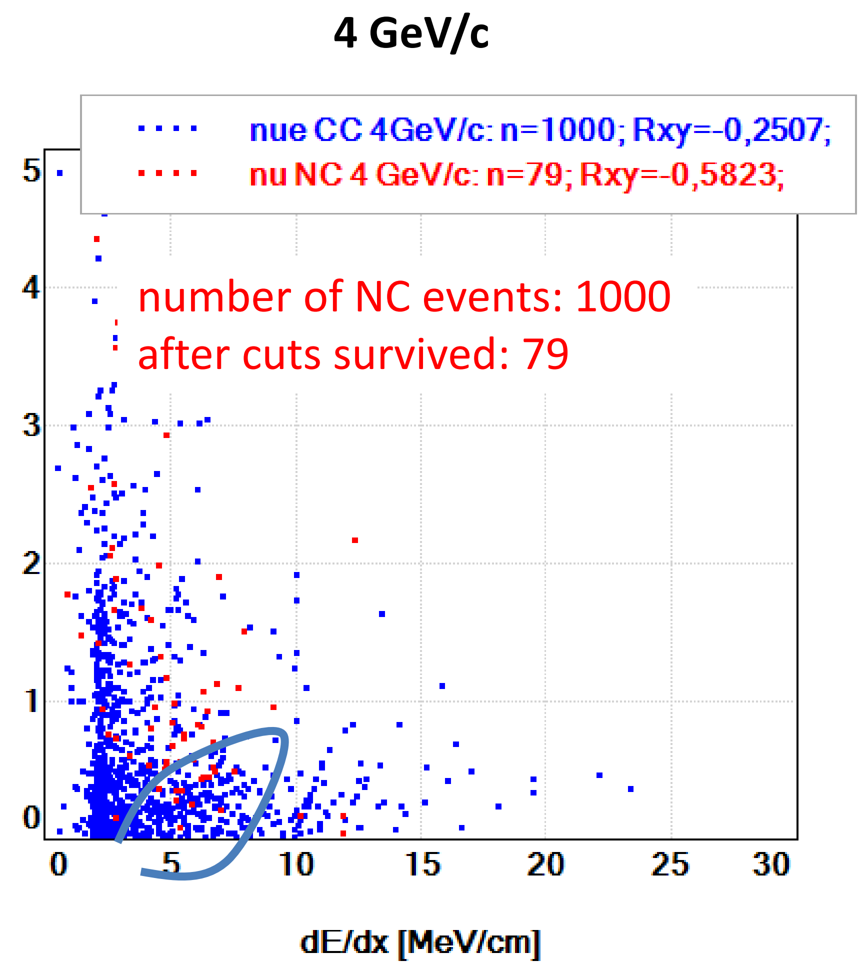


- Cut on gap < 3 wires.

Background rejection

3 views are used





- Higher energies: crowdy vertex, starts to be important to correctly seperate first part of a cascade from other tracks – `reco challenge.`
- In crowdy vertex it is impossible to measure dE/dx of a first part of a cascade.

Some conclusions: background rejection using only gap information

- We have idealistic situation: S/N ~ 10 in views, perfect wires, and **no diffusion**. We know where is primary vertex from MC.

- Background rejection depends on neutrino energy:
  the higher neutrino energy is the bigger background is present

1GeV/c
- 100% efficiency of signal selection.
- 98% background rejection.

2GeV/c
- 100% efficiency of signal selection.
- 97% background rejection.

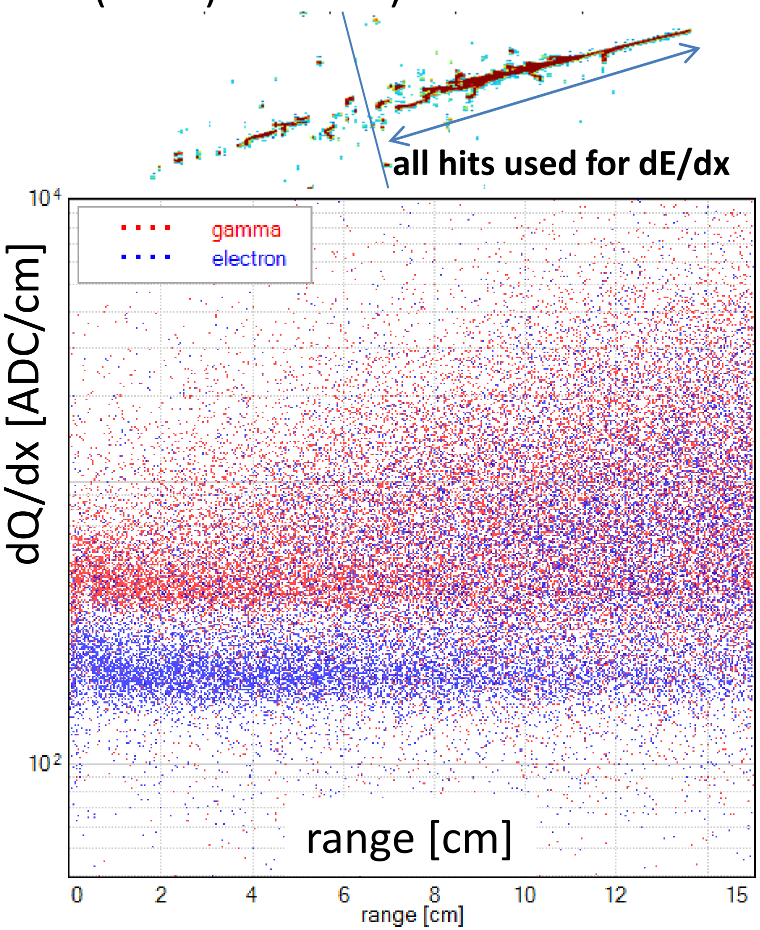
3GeV/c
- 100% efficiency of signal selection.
- 96% background rejection.

4GeV/c
- 100% efficiency of signal selection.
- 92% background rejection.

dE/dx as a discriminant

Neutrino events:

- Crowdy vertex so first part of a cascade is difficult to reconstruct.
- Showers momentum difficult to measure to select showers above 500 MeV.
- Measure dE/dx along axis of a cascade, do not limit ourselves only to 1 m.i.p part, try to find statistical difference also where the showering starts– idea evolved during discussion with Xin, Tom. (1 m.i.p. part had been studied by ICARUS Eur. Phys. J. C (2013) 73:2345).



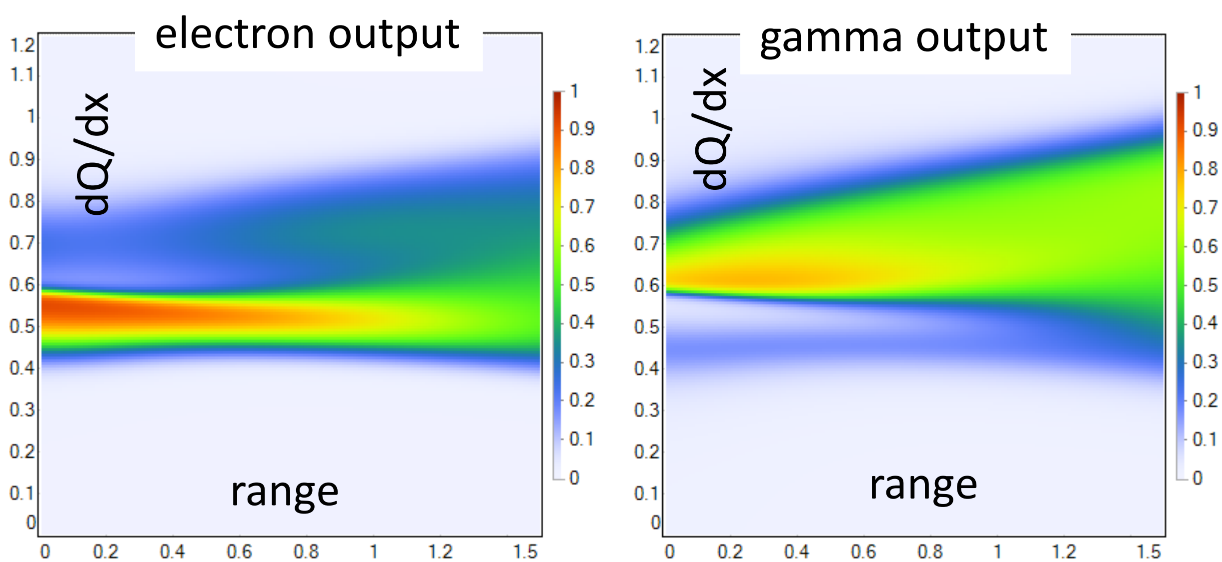
- Simulation in LArSoft: single electron/photons showers with momentum 0.2 – 2 GeV/c.
- Build a segment along cascade with 15 cm length and take all hits in the cascade up to this range.
- The seperation between photons and electrons is good up to about 8-10 cm.
- In full event, likely, we will not see first track up to 3 cm. →we start to study what is the seperation when first cm are invisible.
- Smear range of γ's according to the chance of not observing the gap in background – we are pretending that we do not see where it started.

P(e | dQ/dx, range)   P(γ | dQ/dx, range)

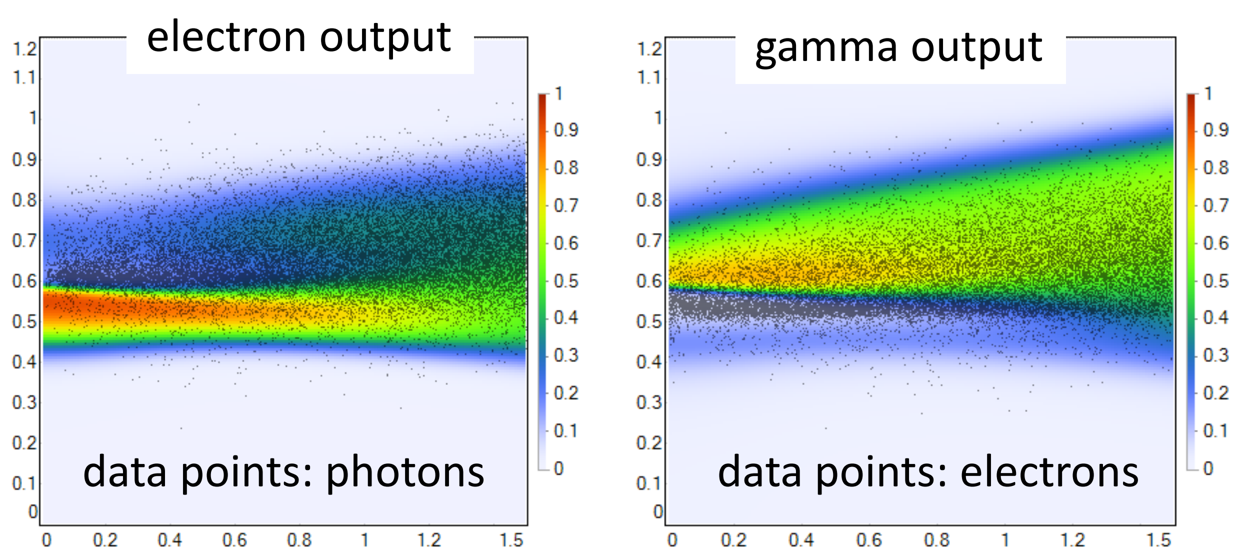
- Made from isolated cascades, gamma range smeared: will change with improved way of making dQ/dx along the cascade.

- We should also take into account missed data points of e or gamma shower overlapped with other tracks near the vertex.

Note: pattern can be quite dependent on the reconstruction chain, this is delicate point, to be addressed…



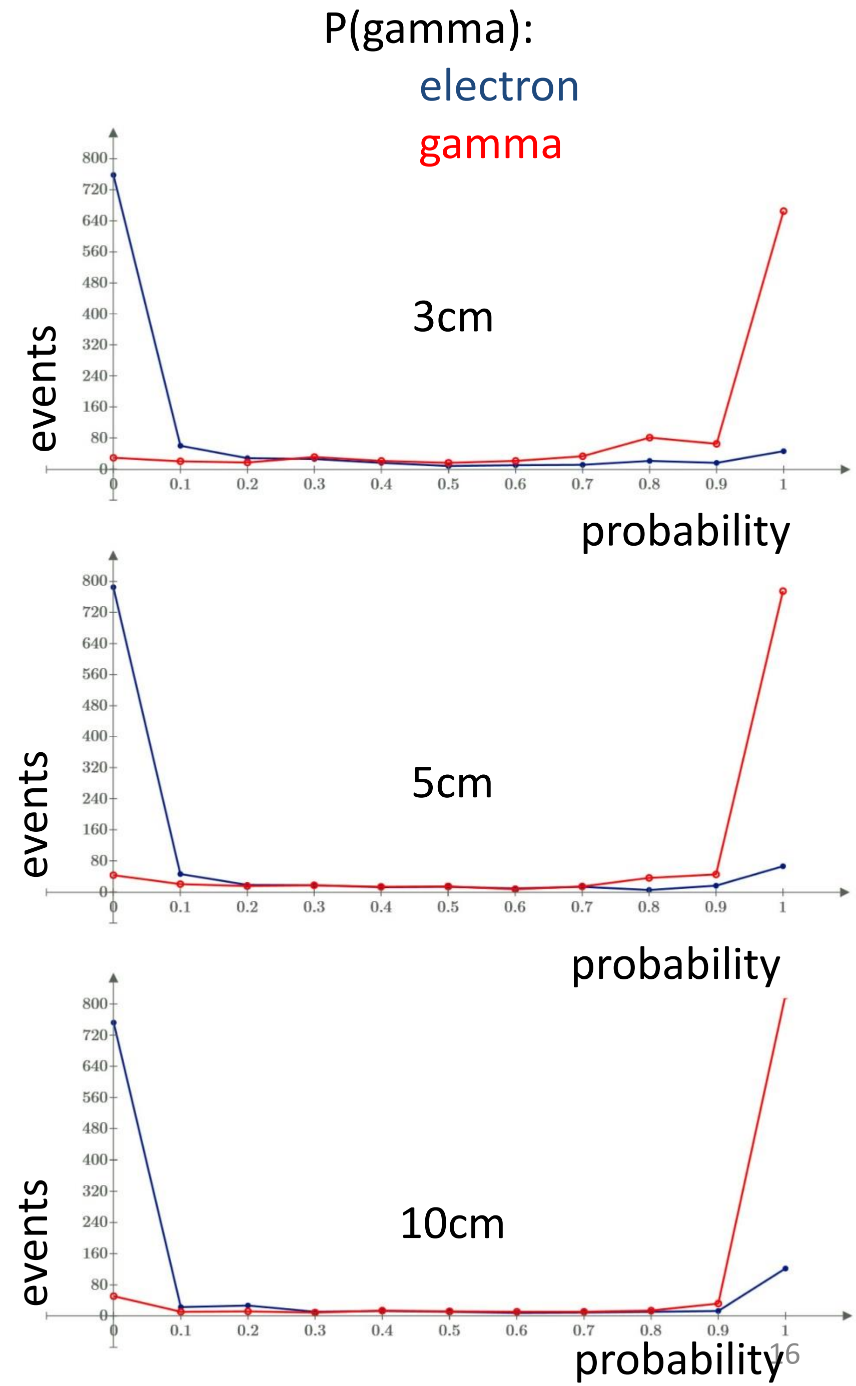
Overlapped with data points of the other class:



First attempt, many things to understand and improve (dQ/dx sequence calculation in the first place)…

The idea like for stopping particles, just we proceed from cascade start instead of track stop point:

- Take dQ/dx along the cascade axis
- Each event can have different number of data points, it is OK
- For each data point check P(gamma), P(electron) and P(none)
- Correlation between data points is far more complicated than for stopping particles, but just ignore that today…
- Accumulate probabilities from all data points to obtain the final value.



Some conclusions: background rejection using gap and dE/dx

Using gap

1GeV/c
- 100% efficiency of signal selection.
- 98% background rejection.

2GeV/c
- 100% efficiency of signal selection.
- 97% background rejection.

3GeV/c
- 100% efficiency of signal selection.
- 96% background rejection.

4GeV/c
- 100% efficiency of signal selection.
- 92% background rejection.

- Results should be slightly improved after applying gap defined in cm.

- After rough studies with the use of dE/dx: background rejection can be even more improved but at the cost of decrease of signal electron efficiency… how much need to be studied.

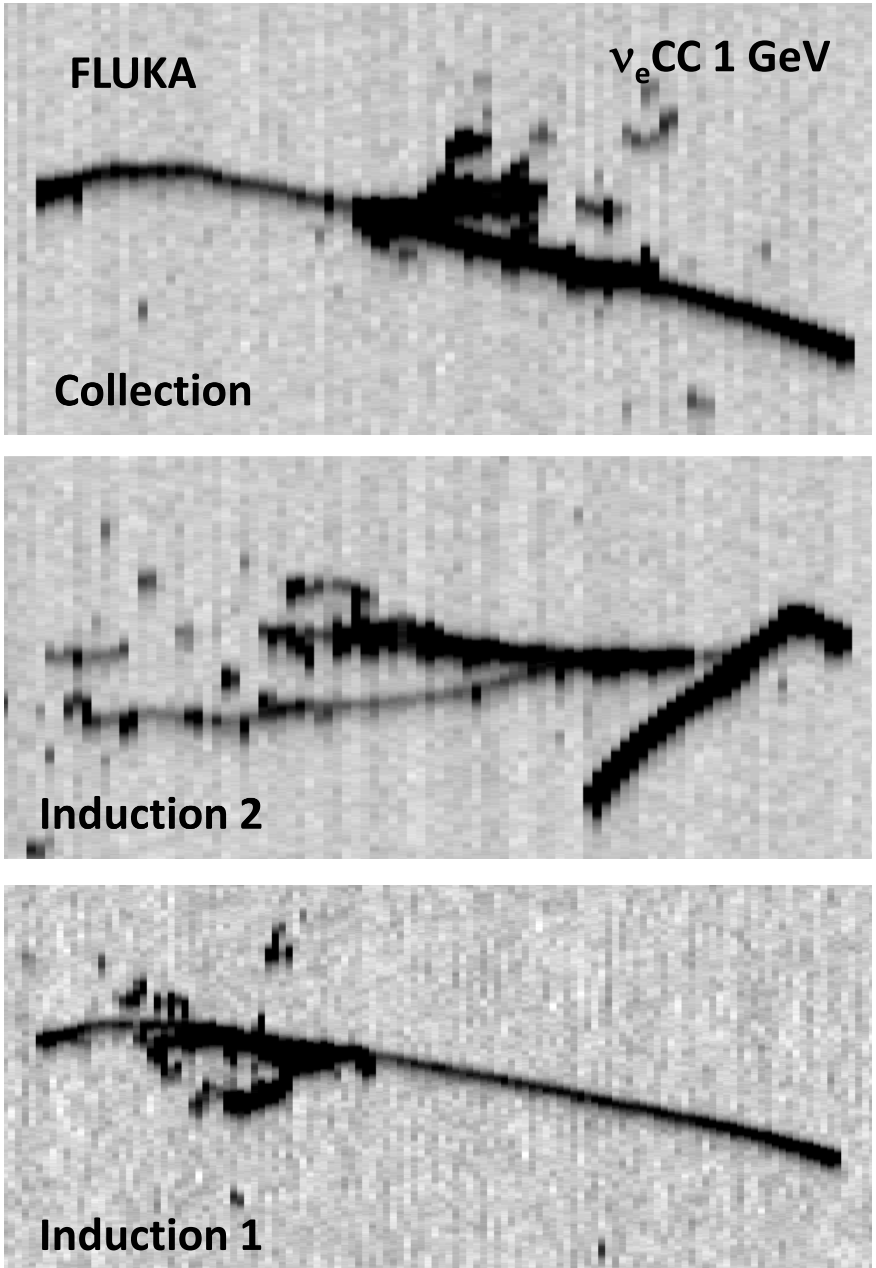
Requirements for combined cuts (gap, dE/dx):
- 90% efficiency of signal selection.
- 99% background rejection.

Reconstruction challenges.

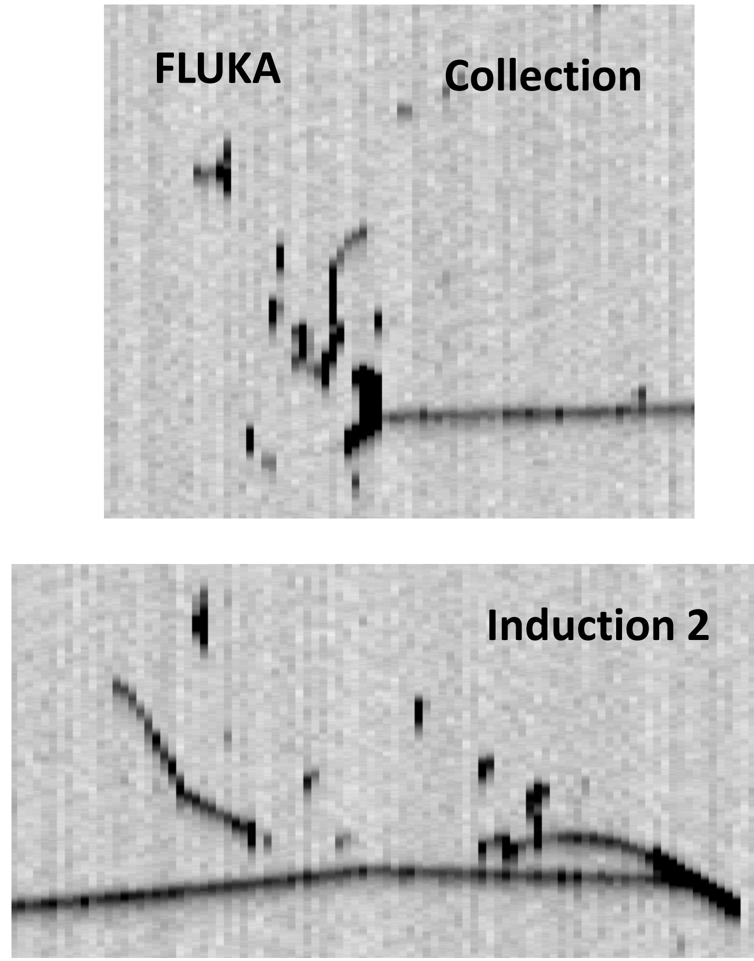
- Region of vertex.
- Correctly collect fragments of shower: many people work on this but it is far from being perfect.

→ It is serious reconstruction challenge, which requires to develop new techniques: long term. It is probably truth for all frameworks.

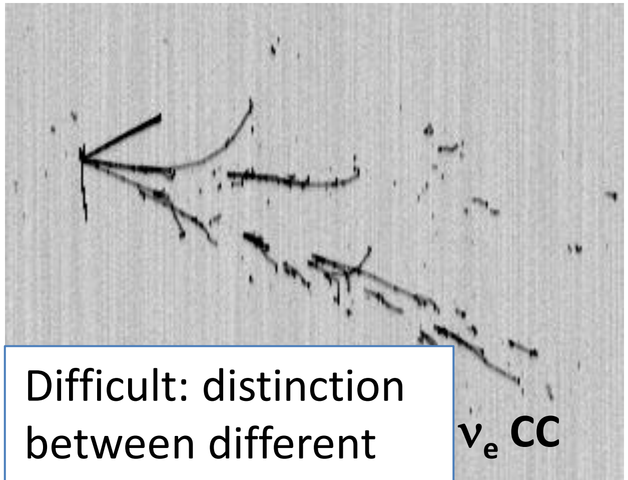
Region of vertices – reconstruction challenge



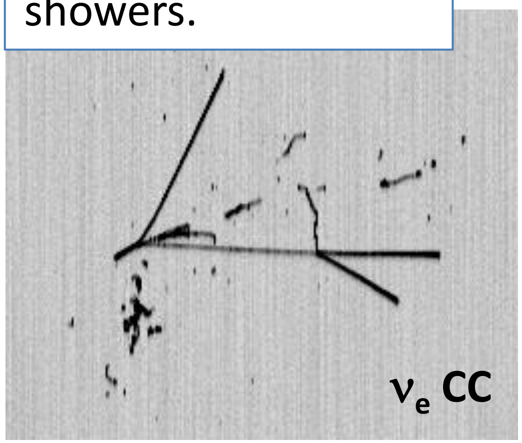
Examples of difficult projections of the showers.

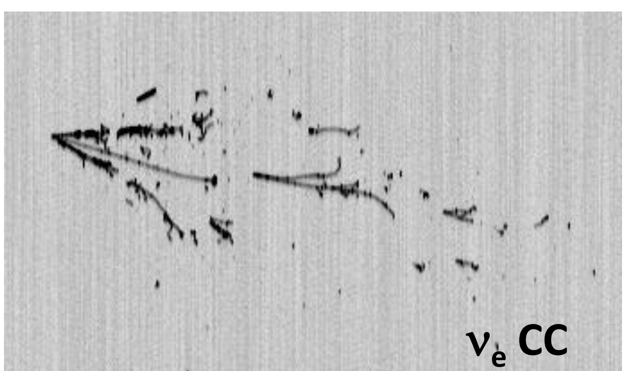


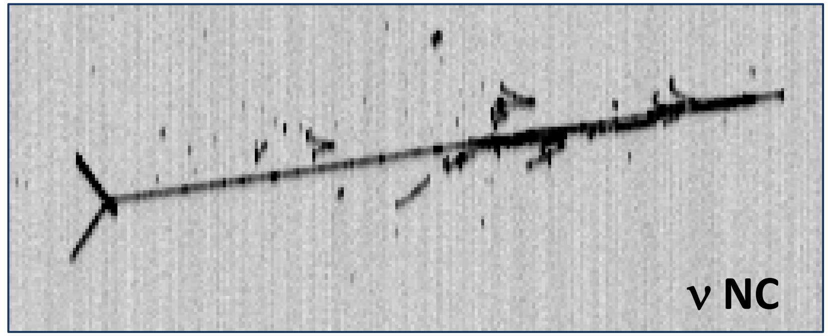
Showers – reconstruction challenge



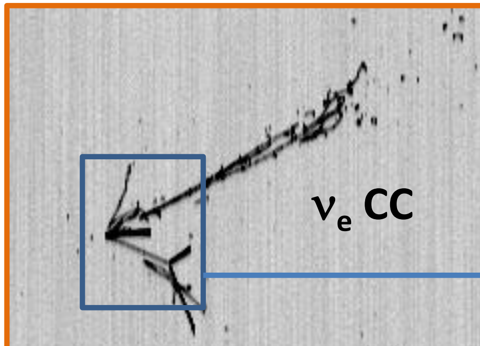
Difficult: distinction between different showers.



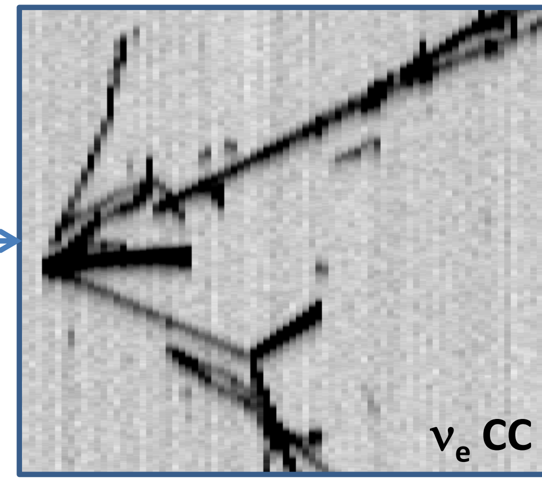




Difficult: tracks overlap



detailed and reliable shower-track seperation is needed.



Reconstruction problem to solve:

- Recognize shower-like clusters.
- Grouping clusters correctly.

Conclusion

- First attempts to separate electron/gamma using the reconstruction in the context of a full neutrino event and with the use of different discriminants.
- We should include both, cuts on gap and dE/dx, we can also add angular cuts and momenta.
- **Urgent**: check what are the results when diffusion is turned on (should be ready for the next meeting).
- For far detector optimization studies it is important to repeat all the studies with different wire pitch and diffusion. It can be done in RECO framework up to 2.5 m drift distance and in LArSoft. We can use both MCC in LArSoft and RECO.
- All detector effects will affect the results:
  from the previous studies S/N > 5 is fine, but more safty is 9., 10. Low S/N affects hit level reconstruction, which are the basic elements of the current reconstruction.
- Important reconstruction challenges are:
  shower reconstruction, and region of vertex. This probably will not be ready before detector parameters will be decided.

backup

Diffusion impact

- When diffusion is included it will affect the minimum conversion length at which gap can be detected.
- What will be the best threshold for a gap in such conditions? – must be studied with diffusion and its relation with electron drift time.

<u>To simulate possible results today, without diffusion, signal criterion is modified: gap < 6 wires.</u>

1 GeV/c → from 98% background rejection to **97%**

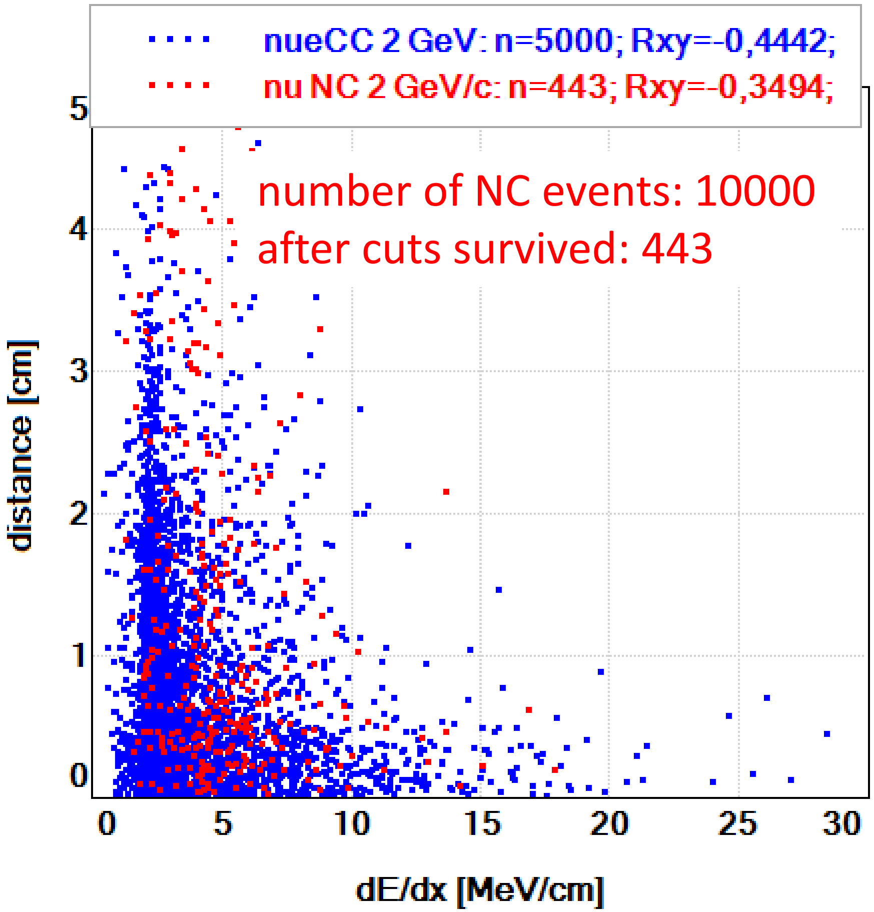
2 GeV/c → from 97% bkg. rej. to **91%**

3 GeV/c → from 96% bkg. rej. to **91%**

4 GeV/c → from 92% bkg. rej. to **85%**

Background rejection estimation using only gap.

Background rejection
2 views are used



- more events processed for 2 GeV/c neutrino momenta using only 2 views.
- In this case much worse background rejection, decrease to **96%** (**97%** when 3 views are available).